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PATENT SPECIFICATION

Inventors: THOMAS VICTOR ARDEN and GEORGE STEPHEN SOLT

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COMPLETE SPECIFICATION

Improvements in Electrolytic Apparatus

We, THE PERMUTIT COMPANY LIMITED, a British Company, of Permutit House, Gunnersbury Avenue, London, W.4, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

Electrodialysis is a well-known process which comprises electrolysing a solution of an electrolyte between two electrodes separated by one or more porous membranes. These membranes allow passage of the ions under the force of the applied current but tend to prevent the electrolytic products formed at or near the electrodes from mechanically mixing with the electrolyte on the far side of the membrane. In this way the electrolytic products are kept separate to a greater or less extent depending on the efficiency of the membranes in preventing this mixing of the ions.

In addition to some mechanical mixing, back-migration of the ions composing the electrode products under the influence of the current also occurs. The porous membranes do not stop this, but since membranes of ion-exchange materials have become available it has been possible to do so substantially completely. For example, in the electrodialysis of sodium chloride use may be made of a cell formed into three compartments by two ion-exchange membranes, a cation-exchange membrane being next to the cathode and an anion-exchange membrane being next to the anode. Then, after passage of current through the cell, chlorine will be formed at the anode some of it being liberated as a gas and some dissolving in the water in the anode compartment, substantially pure water will be left in the centre compartment and substantially pure caustic soda will be formed in the cathode compartment. In addition hydrogen liberated at the cathode will be present in the cathode compartment. If ordinary porous membranes were used, the contents of the three compartments would tend to mix and react, and pure water would not be obtained.

If the number of membranes is increased, cation-exchange membranes alternating with anion-exchange membranes between the two electrodes, and each compartment contains a solution of electrolyte, a somewhat different result is obtained. When a direct current is passed between the electrodes cations move towards the cathode and will pass through cation-exchange material if this is in its way, but will not pass through anion-exchange material. Similarly anions will move towards the anode, passing through anion-exchange material but being obstructed by cation-exchange material. It will be apparent, therefore, that in some compartments there will be no movement of ions outwards, whereas in others the anions will leave the compartment in one direction and the cations in the other, and will enter, from opposite sides, the compartments from which there is no outward movement. Accordingly in the former compartments the solution will become more concentrated while in the latter the solution will become diluted. In the end compartments containing the electrodes, however, the action is similar to that in a three-compartment cell. For example, in the electrodialysis of sodium chloride, chlorine will be formed in the anode compartment and caustic soda and hydrogen in the cathode compartment.

A disadvantage of a multi-compartment cell as just described is that if it is to have any considerable capacity for treating water or other liquid in continuous flow it must consist of a large number of very narrow compartments through which liquid must flow in parallel streams, and the introduction of the liquid into and removal of it from these compartments involves considerable difficulties. In addition many separate membranes are required.

According to this invention a cation-

exchange membrane and an anion-exchange membrane are wound round a central electrode and within an outer electrode to form two continuous compartments which alternate across any radius from the central electrode. The compartments are closed transverse to the axis around which the membranes are wound. Although there are in fact only two compartments, they behave in the same way as the separate compartments of the known multi-compartment cell, since the current flows along all the radii from one electrode to the other and in so doing traverses as many compartments as there are turns of the pair of membranes; there may be from 2 to 200 or more such turns.

Each membrane is preferably anchored to both electrodes through electrical insulation.

In the simplest arrangement the membranes are spirally wound around a cylindrical former, which may advantageously be the central electrode, and lie within a cylindrical outer electrode, each membrane being joined to one electrode at one end and to the other at the other end.

This preferred arrangement is shown in the diagrammatic drawing accompanying the provisional specification, which is a transverse section through a cell. The cylindrical former which is also the central electrode is shown at 1 and the cylindrical outer electrode at 2. The two membranes are shown at 3 and 4 and the compartments at 5 and 6. Assuming that the electrode 1 is the anode, the membrane 3, which is adjacent to nearly the whole circumference to the electrode 1, has anion-exchange properties, and the membrane 4, which is adjacent to nearly the while inner surface of the electrode 2, has cation-exchange properties.

Although it is possible for electrodialysis to be carried on in batch fashion with static liquids in both compartments, it is much more convenient and advantageous to pass the solution of the electrolyte to be electrodialysed continuously in one of the spiral paths between the two electrodes, the liquid in which the removed electrolyte is to be collected being passed continuously in the other spiral path. Alternatively there may be continuous passage of liquid in one path only. Passages for the introduction and discharge of the liquids must therefore be provided. For this purpose two ports 7 and 8 communicating with the compartments are made in the outer electrode 2. Each of these ports preferably consists of a series of holes in axial alignment, putting the two compartments 5 and 6 in communication with pipes 9 and 10. Ports 11 and 12 are formed in the inner and hollow electrode communicating with two axial spaces 13 and 14 into which the electrode is divided by the wall 15, which is axially coextensive with the electrode. The membranes are anchored to the electrode 1 on the opposite sides of the port 12 by electrically insulating material 16, and anchored to the electrode 2 on the opposite sides of the port 8 by electrically insulating material 17. Openings are made in one or other end of the cell to connect the spaces 13 and 14 to pipes similar to the pipes 9 and 10.

To explain the operation, assume that the solution of electrolyte to be electrodialysed is sea water. The water to be desalted is introduced through the space 14 and port 12 into the compartment 6 and flows out through the port 8 and pipe 10. The liquid in which the removed electrolyte is collected, which may also be sea water, is introduced into the compartment 5 through the pipe 9 and port 7 and flows out through the port 11 and central space 13. In its initial flow through the compartment 6 the water is separated from the electrode 1 by the membrane 3 and part of the compartment 5, and in its final flow the water is separated from the electrode 2 by the membrane 4 and compartment 5. Ions are driven in both directions through the membranes from the compartment 6 into the compartment 5, and if the compartments are long enough and the current large enough substantially all the ions in the water will have been driven out of it by the time it reaches the port 8 and will be found in the water passing through the port 11.

The operation will not proceed exactly as described if the compartment 6 is in direct contact with either electrode as an electrode reaction will then take place in the liquid being purified. It is for this reason that the compartment 6 is shielded from the cathode 2 by the electrical insulation 17 and from the anode 1 by the electrical insulation 16.

In the process described, the two flows are countercurrent, but they can be concurrent. If countercurrent operation is used the highest purity water will be obtained; but concurrent operation has some advantages since it is possible, by removing part of the insulation 16 at the anode 1, so that it does not wholly isolate the anode from the compartment 6, to allow gas released at the anode, in this case chlorine, to dissolve in the liquid in the compartment 6. The amount of chlorine produced at this point can be controlled by varying the area of anode exposed. Some of the chlorine so formed enters the stream of water which is to be purified, and is not removed by the action of the electrolytic cell. The overall process thus consists of demineralisation coupled with controlled chlorination.

The turns of the membranes should preferably be separated from one another by electrical insulation in contact with both membranes to form the two compartments. The electrical insulation may be coated on integral projections on one face of each membrane the projections bearing against the adjacent plane face of the next turn of the other membrane.

Again, corrugated spacing sheets may be put on each side of one membrane before the cell is made, and the four sheets (two membranes and two corrugated sheets) are then wound together. Yet again, the edges of the membranes may be thickened, the liquid serving to keep the unthickened parts out of contact with one another, or narrow and thin bands of rubber or a plastic may be interposed between the edges of membranes of uniform thickness. Such thickened parts or narrow bands may form seals for the compartments at the two end faces of the cell, but since it is also necessary to close the ends of the central space it is preferred to stick a disc on to each face as an end cap.

To ensure equal distribution of flow of liquid axially across each compartment through the length of the spiral, when ribs of corrugated spacers are used they must be arranged to form channels, preferably parallel along the length of each compartment from one end of each compartment to the other. The channels should then have restrictions placed at their ends, in order that the pressure loss through the channels may be greater than that through the entry pipes and ports.

Instead of using the central former as an electrode, a rod within the central space may serve as the central electrode.

The membranes need not be wound cylindrically. They may, for instance, be wound polygonally, pins extending between end caps being used as corner guides.

What we claim is:—

1. An electrodialytic cell made up of a cation-exchange membrane and an anion-exchange membrane wound round a central electrode and within an outer electrode to form two continuous compartments which alternate across any radius from the central electrode.

2. A cell according to Claim 1 in which the membranes are spirally wound round a central cylindrical electrode within a cylindrical outer electrode.

3. A cell according to Claim 2 in which each membrane is anchored to both electrodes through electrical insulation.

4. A cell according to Claim 3 in which one compartment is shielded from the cathode and the anode by the electrical insulation.

5. A cell according to Claim 4 in which the electrical insulation does not wholly isolate the anode from the one compartment, so as to allow gas released at the anode to dissolve in the liquid in that compartment.

6. A cell according to any of Claims 3 to 5 in which the inner electrode is hollow and divided into two axial spaces respectively communicating with the two compartments by ports in the electrode, and ports communicating with the compartments are made in the outer electrode, whereby liquids can continuously flow through both compartments.

7. A cell according to any of the preceding claims in which the turns of the membranes are separated from one another by electrical insulation in contact with both membranes.

8. A cell according to Claim 7 in which the electrical insulation is coated on integral projections on one face of each membrane.

9. A cell according to Claim 1 substantially as described with reference to the accompanying drawing.

10. A process of electrodialysing a solution of an electrolyte which comprises passing it continuously in a spiral path between two electrodes, the path being defined by an anion-exchange membrane and a cation-exchange membrane, the liquid in which the removed electrolyte is collected being passed continuously in a second spiral path defined by the membranes.

11. A process according to Claim 10 in which the solution and the liquid pass between the electrodes countercurrent to one another.

12. A process according to Claim 10 in which the solution is salt water and it and the liquid pass between the electrodes concurrent with one another, the desalted water being chlorinated by chlorine produced by an electrode reaction at the anode.

For the Applicants,
GILL, JENNINGS & EVERY,
Chartered Patent Agents,
51/2 Chancery Lane,
London, W.C.2.

PROVISIONAL SPECIFICATION

Improvements in Electrolytic Apparatus

We, THE PERMUTIT COMPANY LIMITED, a British Company, of Permutit House, Gunnersbury Avenue, London, W.4, do hereby declare this invention to be described in the following statement:—

Electrodialysis is a well-known process which comprises electrolysing a solution of an electrolyte between two electrodes separated by one or more porous membranes. These membranes allow passage of the ions under the force of the applied current but tend to prevent the electrolytic products formed at or near the electrodes from mechanically mixing with the electrolyte on the far side of the membrane. In this way the electrolytic products are kept separate to a greater or less

extent depending on the efficiency of the membranes in preventing this mixing of the ions.

In addition to some mechanical mixing, back-migration of the ions composing the electrode products under the influence of the current also occurs. The porous membranes do not stop this, but since membranes of ion-exchange materials have become available it has been possible to do so substantially completely. For example, in the electrodialysis of sodium chloride use may be made of a cell formed into three compartments by two ion-exchange membranes, a cation-exchange membrane being next to the cathode and an anion-exchange membrane being next to the anode. Then, after passage of current through the cell, chlorine will be formed at the anode, some of the chlorine being liberated as a gas and some dissolving in the water in the anode compartment, substantially pure water will be left in the centre compartment and substantially pure caustic soda will be formed in the cathode compartment together with hydrogen which is liberated at the cathode. If ordinary porous membranes were used, the contents of the three compartments would tend to mix and react, and pure water would not be obtained.

If the number of membranes is increased, cation-exchange membranes alternating with anion-exchange membranes between the two electrodes, and each compartment contains a solution of electrolyte, a somewhat different result is obtained. When a direct current is passed between the electrodes cations move towards the cathode and will pass through cation-exchange material if this is in its way, but will not pass through anion-exchange material. Similarly anions will move towards the anode, passing through anion-exchange material but being obstructed by cation-exchange material. It will be apparent, therefore, that in some compartments there will be no movement of ions outwards, whereas in others the anions will leave the compartment in one direction and the cations in the other, and will enter, from opposite sides, the compartments from which there is no outward movement. Accordingly in the former compartments the solution will become more concentrated while in the latter the solution will become diluted. In the end compartments containing the electrodes, however, the action is similar to that in a three-compartment cell. For example in the electrodialysis of sodium chloride caustic soda and chlorine will be formed.

A disadvantage of a multi-compartment cell as just described is that if it is to have any considerable capacity for treating water or other liquid in continuous flow it must consist of a large number of very narrow compartments through which liquid must flow in parallel streams, and the introduction of the liquid into and removal of it from these compartments involves considerable difficulties. In addition many separate membranes are required.

According to this invention, two long ion-exchange membranes, one having cation-exchange and the other anion-exchange properties, are wound round a central electrode and within an outer electrode to form two continuous compartments which alternate across any radius from the central electrode. One of these compartments leads to the central electrode and the other to the outer electrode. The compartments are closed transverse to the axis around which the membranes are wound. Although there are in fact only two compartments, they behave in the same way as the separate compartments of the known multi-compartment cell, since the current flows along all the radii from one electrode to the other and in so doing traverses as many compartments as there are turns of the pair of membranes; there may be from 2 to 200 such turns.

In the simplest arrangement the membranes are spirally wound around a cylindrical former, which may advantageously be the central electrode, and lie within a cylindrical outer electrode. Each membrane is joined to one electrode at one end and to the other at the other end.

This preferred arrangement is shown in the accompanying drawing, which is a transverse section through the cell. The cylindrical former and central electrode is shown at 1 and the cylindrical outer electrode at 2. The two membranes are shown at 3 and 4 and the compartments at 5 and 6. Assuming that the electrode 1 is the anode, the membrane 3, which is adjacent to nearly the whole circumference of the electrode 1, has anion-exchange properties, and the membrane 4, which is adjacent to nearly the whole inner surface of the electrode 2, has cation-exchange properties.

Although it is possible for electrodialysis to be carried on in batch fashion with static liquids in both compartments, it is much more convenient and advantageous to cause liquid to flow continuously through both compartments, or at least through one of them. Passages for the introduction and discharge of the liquids must therefore be provided. For this purpose two ports 7 and 8 are made in the cylindrical wall of the electrode 2, each of these ports preferably consisting of a series of holes in axial alignment, putting the two compartments 5 and 6 in communication with pipes 9 and 10. Ports 11 and 12 are made in the cylindrical wall of the electrode 1, the port 11 putting the compartment 5 in communication with the central space 13 within the electrode 1, and the port 12 putting the compartment 6 in communication with a space 14 lying inside the electrode 1 but

separated from the space 13 by a wall 15 which is axially co-extensive with the electrode. The membranes are joined to and electrically insulated from the electrode 1 on the opposite sides of the port 12, and joined to and electrically insulated from the electrode 2 on the opposite sides of the port 8, as shown in the drawing. Openings are made in one or other end of the cell to connect the spaces 13 and 14 to pipes similar to the pipes 9 and 10.

To explain the operation, assume that sea water is to be purified. The water is introduced through the space 14 and port 12 into the compartment 6 and flows out through the port 8 and pipe 10. Further water, which may be the same as that to be purified, is introduced into the compartment 5 through the pipe 9 and port 7 and flows out through the port 11 and central space 13. In its initial flow through the compartment 6 the water is separated from the electrode by the membrane 3 and part of the compartment 5, and in its final flow the water is separated from the electrode 2 by the membrane 4 and compartment 5. Ions are driven in both directions through the membranes from the compartment 5 into the compartment 6, and if the compartments are long enough and the current large enough substantially all the ions in the water will have been driven out of it by the time it reaches the port 8 and will be found in the water passing through the port 11.

The operation will not proceed exactly as described if the compartment 6 is bounded by any part of either electrode due to an electrode reaction taking place in the liquid being purified. It is therefore preferred to render insulating instead of conducting those parts of both the cylinders 1 and 2 which bound the compartment 6, so that these parts cease to act as parts of the electrodes. The insulation on the cylinder 1 is shown at 16 and that on the cylinder 2 at 17.

In the example given, the two flows are countercurrent, but they can be concurrent. If countercurrent operation is used the highest purity water will be obtained, but concurrent operation has some advantages since it is possible, by removing part of the insulation 16 at the anode 1, to introduce a controlled amount of chlorine production at this point. The chlorine so formed enters the stream of water which is to be purified, and is not removed by the action of the electrolytic cell. The overall process thus consists of demineralisation coupled with controlled chlorination.

The membranes should be positively spaced apart from one another to form the two compartments. Each may be made with ribs on one face for this purpose, the ribs bearing against the adjacent plain face of the next turn of the other membrane and preferably being coated with electrical insulation to prevent short-circuiting. Again, corrugated spacing sheets may be put on each side of one membrane before the cell is made, and the four sheets (two membranes and two corrugated sheets) are then wound together. Yet again, the edges of the membranes may be thickened, the liquid serving to keep the unthickened parts out of contact with on another, or narrow and thin bands of rubber or a plastic may be interposed between the edges of membranes of uniform thickness. Such thickened parts or narrow bands may form seals for the compartments at the two end faces of the cell, but since it is also necessary to close the ends of the central space it is preferred to stick a disc on to each face as an end cap.

To ensure equal distribution of flow of liquid axially across each compartment through the length of the spiral when ribs or corrugated spacers are used, it is preferred to arrange them to form parallel channels along the length of each compartment. The parallel channels should then have restrictions placed at their ends, as described in our Application No. 23,131/53, in order that the pressure loss through the channels may be greater then that through the entry pipes and ports.

Instead of using the central former as an electrode, a rod within the central space may serve as the central electrode.

The membranes need not be spirally wound. They may, for instance, be wound as polygons, pins extending between end caps being used as corner guides.

For the Applicants,
GILL, JENNINGS & EVERY,
Chartered Patent Agents,
51/52, Chancery Lane,
London, W.C.2.

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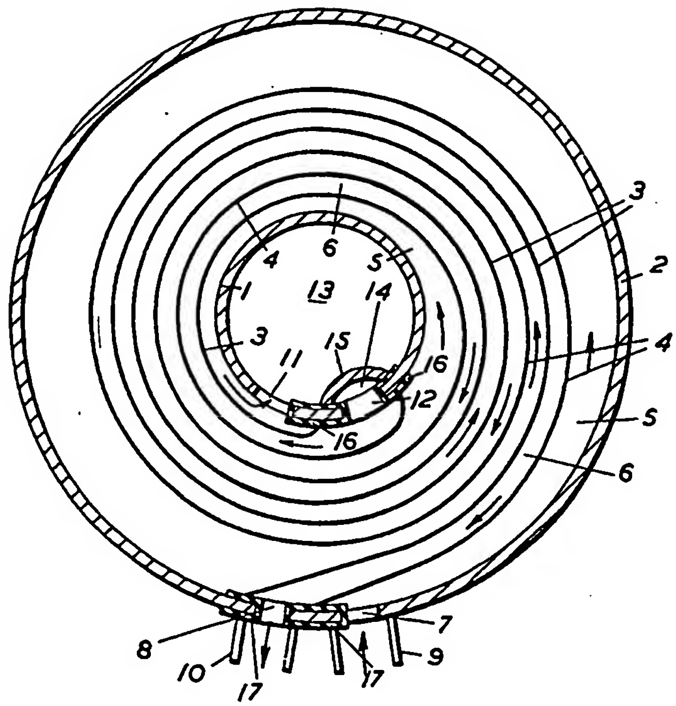
1 SHEET This drawing is a reproduction of the Original on a reduced scale



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